

Draft Thematic Plan

Isotope Hydrology in Dam Safety and Sustainability

Background/Justification

The Agency's objective is to promote the use of environmentally safe isotope techniques for development purposes. The sustainability and safety of dams and reservoirs have been identified, through feedback from governments, as areas where the application of isotope hydrology can have a major impact on socio-economic development. This impact is in terms of both cost-savings and safety. For this reason, the DDG-TC decided that a thematic plan was to be prepared in this sector.

In line with the TC strategy, the thematic plan aims to identify the end-users for isotope technologies and draw up a strategy for adapting its technical co-operation to produce socio-economic impact through these end-users. Synergies will be sought with partner organisations, so that it is expected that the expanded use of isotope methods in dam management will strengthen TC while assisting the World Bank and other funding organisations - as well as NGOs and private sector organisations - in achieving their programme objectives.

1a. The development need, technical solution and role of nuclear technology

Development problem

Dam reservoirs are extremely valuable assets to their owners and to the communities that depend on them for agriculture, power, flood control and other uses. Dams are the investments that are engineered and constructed to create the reservoirs and hold water in them. Dams and reservoirs are vital to the sustainability of a large part of the world's population for water supply, irrigation, flood protection and hydropower. Their ability to function properly for a long time is crucial to the well being of these population segments.

Very large investments are therefore necessary each year for increasing the efficiency of dam and reservoir operations and thereby improving socio-economic development. The funds are largely used for engineering and construction to mitigate three types of problems:

- leakage from reservoirs that flows under and around dams
- leakage through dams and through the foundations and abutments
- sediments that have deposited in the reservoir and depleted its storage capacity.

The magnitude of these problems are illustrated by the following facts:

- ⇒ Millions of US \$ are invested each year to for grouting and sealing following real and suspected leaks from reservoirs.
- ⇒ Studies¹ show that, world-wide, an average 1% of reservoir capacity is lost every year due to sedimentation, and the average age of reservoirs is limited to around 22 years.

All dams are designed to lose water by a phenomena known as seepage, which actually helps make the dam more stable. Controls to keep seepage to an acceptably low level are designed and built into the dam and its foundations. Leakage occurs when seepage is concentrated through a weak zone in the dam or a pathway in the foundation or abutment. Seepage is typically controlled by conventional means. Leakage can present a more serious problem especially if it is carrying sediment.

Information gap

The role of nuclear techniques in dam management is to generate information to help end-users make decisions that will guide, optimise and protect investments in dam safety and sustainability. Isotope investigations can help identify and contribute to the solution of a problem. From the point of view of the end-users of the technology, isotope techniques are among many available technical tools - sometimes an indispensable tool and sometimes a useful complement to conventional techniques (The end-users are the owners and operators of dams and reservoirs, and private sector business enterprises consisting of the consultant that engineered and designed the project, and the contractor that built the dam).

However, one of the main impediments to effective integration of isotope techniques in dam safety and sustainability is the lack of knowledge and understanding for their role among end users. It is estimated that less than 5% of end-users in the dam sector are aware of the existence and potential of isotope hydrology in dam management. Likewise, the Agency's counterparts in isotope hydrology laboratories are largely unaware of the needs and requirements of end-users in the dams and reservoirs sector.

Technical solution

Isotope hydrology offers techniques for assisting with site selection, site investigations, watershed studies, dam and reservoir design, dam construction, dam and reservoir leakage investigations, sediment control and prolonging reservoir longevity. Most of the techniques play a catalytic role by supplementing conventional technology for solving dam management problems from planning through operations. The techniques for tracing and identifying water sources and leakage are validated and are well known. Isotopes can also be used to fingerprint sediments and determine their composition and origin so that rational plans can be made for removing sediment from the reservoir, relocating sediment within the reservoir, and developing watershed management plans.

Some isotope methods, while having the potential of providing new and unique technologies for addressing specific dam and reservoir problems, need further research and development. This includes isotope methods for tracing the origin of sediment within the watershed system. These methods must be validated before they can become accepted tools for dam management.

Applications can be divided into the following problem areas:

1. Dam Engineering
 - 1.1 Pre-feasibility Studies
 - 1.2 Site Selection
 - 1.3 Faulting Studies
 - 1.4 Stability and Seepage Analyses

2. Dam construction
 - 2.1 Quality Control
 - 2.2 Grouting
 - 2.3 Moisture Content
 - 2.4 First Filling
3. Dam Operation
 - 3.1 Monitoring Behaviour
 - 3.1.1 Leakage Through Dams
 - 3.1.2 Leakage Around Dams
 - 3.1.3 Suspected Leakage Downstream of Dams
 - 3.2 Sedimentation
 - 3.2.1 Source
 - 3.2.2 Behaviour
 - 3.3 Reservoir Life

A more comprehensive list of applications is provided in the matrix below:

Table 1 - Isotope Techniques in Dam Management

APPLICATIONS	Techniques to be used	STAGE		
		Planning & Designing	Construction & Commissioning	Operation
Basic hydrologic and isotopic information	EI, Ch	C,v	C,v	
Origin of water in paleorivers underneath dam sites	EI, Ch	C,v	C,v	
Monitoring Reservoir Induced Seismicity at specific geostructures.	Rn	C,l	C,l	C,l
First filling seepage/leakage monitoring	EI, AT		C,v	
Origin of leakage (reservoir or not)	EI		P,v	P,v
Identification of entry zone of leakage	AT, RI		C,v	C,v
Labeling of entry zone	RI		P,v	P,v
Leakage path within the dam body	AT, RI		C,v	C,v
Groundwater regime around reservoir	EI, AT, RI		C,v	C,v
Measuring density of injected mix in grouting operations	NP		P,l	P,l
Dating sediments in a reservoir	Cs, Pb			P,v
Sediment density	NP		C,v	C,v
Density current monitoring	NP			P,l
Sediment routing during peak turbidity inflow by real time	NP			P,l

density monitoring

Watershed erosion, sediment fingerprinting, zones of erosion/aggradation	Cs, Pb, INAA	P,l	P,l	P,l
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NOTES:

Techniques: EI = Environmental isotopes (^{18}O , Deuterium, Tritium, ^{13}C)
AT = Artificial Tracers
Ch = Chemistry
Rn = Radon-222 emanation from rocks
RI = Radioisotopes
Cs = Caesium-137 (fallout)
Pb = Lead-210 (Natural, unsupported)
NP = Nuclear probe
INNA = Instrumental Neutron Activation Analysis and other available trace analytical methods

Comparative

Advantage: P = Primary
C = Complementary

Reliability: v = validated
l = likely

Comparative assessment of available solutions

The use of artificial tracers can be helpful in understanding dam and reservoir leakage problems. The only available artificial tracers for labelling large amounts of water during long periods of time are fluorescent dyes (uranine, rhodamine WT or B), injected radioactive isotopes such as iodine-131 (half-life 8 days) or existing radioactive tracers like tritium (half-life 12 years). Fluorescent dyes can be used as water tracers in dam leakage studies. However, to identify the entry zone of leaks, the detection of the tracer 'in situ' is needed. The only available choices are gamma radioactive tracers, iodine-131 and gold-198, the latter as an adsorbable tracer with a half-life of 2.7 days.

Artificial tritium may be the only choice of isotope when very high volumes of water need to be labelled (more than 10^8 m^3).

The tendency is to use radioactive tracers only where other conventional, non radioactive tracers are not well suited. Even considering that the quantity of radioactivity used in the tests and the final concentrations resulting after mixing with the water of the reservoir are very low, public opinion or resistance from the dam owners may represent a serious concern.

The use of radioactive tracers for dam leakage studies must be carried out by licensed people following the national regulations. In some countries, national nuclear research institutes have developed specialised teams with the necessary equipment to perform these activities. They can be invited to participate in the studies in order to safely use radioactive techniques.

1b. Description of the sub-sector

General

According to the International Commission on Large Dams (ICOLD), a dam is classified as large when:

- It is higher than 15 m
- It is between 10 and 15 m high and:
 - a) has a crest length exceeding 500 m, or
 - b) its spillway capacity is in excess of 2,000 cubic meters per second, or
 - c) its reservoir capacity exceeds 1,000,000 cubic meters, or
 - d) has unusual characteristics

This is an arbitrary classification, but it is the most used one the world over. Small dams are dams that do not meet the above criteria.

The oldest dams according to documented evidence were located in Jordan around 3000 BC. Several hundred dams, more than 10 m high, were built before 1800 in about ten Asian countries, around the Mediterranean, and in America. Many ancient dams have disappeared, but some are still operational 500 or 1000 years after being built. By 1930, more than 2000 large dams had been built around the world, 75% of which were in Japan, Great Britain and USA. Dam construction showed a sharp upsurge from the 1950s onward. The highest construction rates occurred in the 1970s when 350 to 400 large dams were put in operation each year.

Based on the best available evidence the total number of large dams, at the end of 1998, is estimated to be in the order of 45,000. About 45% of such dams are for irrigation purposes and roughly one third of them have a multipurpose function. There is no reliable data on the number of small dams in the world. However it has been estimated that this number is about 800,000. Many of these dams are located above populated areas, and are important to the sustainability of the area they serve. Therefore, for dam management purposes, these dams should be treated with the same importance as large dams.

Dams are built out of locally available materials. The best use is made of these materials to design dams that are effective in holding water and economic to build. Therefore, the type of dam and its design are very site specific. Because natural materials vary in quality, unlike products made in a factory, the design and construction of a dam are a challenge of storing the most water for a reasonable cost.

Dam active countries

The total number of dams under construction in 1997 were estimated to be 1,738 (re.: ICOLD's circular #1443). Countries active in building dams (those with at least 10 dams under construction) were the following:

Dam active countries	
Country	<i>Dams under construction in 1997</i>
India	650
China	302
Turkey	236
Republic of Korea	145
Japan	107
Iran	69
Brazil	41
USA	36
Spain	31
Romania	29
South Africa	18
Zimbabwe	13
Indonesia	10
Other	51
<i>Total</i>	1738

Around the world, 242 large dams were put in operation in the year 1997.

Dam safety

Dams are among the highest loaded structures in the world. Their reservoirs hold masses of water with immense potential energy. The effects of failure of a dam or its appurtenances can be disastrous for large populations, cultural resources and the environment, as illustrated by recent disasters such as Teton, Vajont, Malpassat and Boliden. Therefore, dams must have safety built in as a key component.

Safety in dam management is defined by how much a live load can increase before non-permitted deformations or destruction will occur. There are different safety factors for different types of dams. Another component of safety is the probability of natural phenomena such as earthquakes, floods and landslides, and war or sabotage. Safety can be considered as a measure of probability: A safer dam has less probability of failure. Dam safety requirements are high because dams are complex due to their size, loads, construction materials, chemical and weather influences, non-uniform geology, and foundation interaction. These constraints make it difficult to model dams and predict their behavior. Design oversights, construction defects, and aging also reduce safety. High safety factors will increase dam costs, but will reduce the potential for failure.

Ethical considerations

Mr. Palmieri to draft one to two short para. (Many NGOs opposed, , risk being criticised by greens.)

Key stakeholders and end-users

The key participants, or stake-holders, involved in the engineering, construction and operations of work for new dams and for modifying or repairing existing dams are:

The Owner (an end-user)
Management

Operations

Regulatory Authorities

National

State or equivalent

Funding Authorities

Private Sector

Consultant Engineer (an end user)

Specialist Sub consultant

Contractor (an end user)

Specialist Sub contractor

Dam Project Implementation Unit

Instrument Makers

Impacted Residents

These stake-holders have major roles in the project as follows:

	Planning & Design	Construction & Commissioning	Operation Owner
	x	x	xx
Regulatory Authority	x	x	x
Funding Agency	x	xx	x
Private Sector			
Consultant	xx	x	x
Contractor		xx	x
Residents	x		x
Project implementation units	xx	x	x
Instrument-makers	x	x	x

OWNERS

Whether a dam project is privately or government owned depends on the country and the size of its infrastructure. In developing countries, as well as many developed ones, the owner of a large project is more likely to be a government institution such as a Ministry of Irrigation, Power or Water, under a cabinet ranking minister. Or it could be an authority wholly owned by government such as a Power Company or an Irrigation Authority.

In countries where privatisation has been introduced there is a greater chance of the owner being a private company: a water company for example or a hydropower company. Mining companies and railways are also examples of private owners. Private owners appear to be more frequent in the USA, UK, and parts of Latin America.

A characteristic of an owner in the private sector is to retain only staff needed to maintain the infrastructure so that the desired cash flow from the dam and reservoir is maintained. A private firm may therefore be more sensitive to shareholder value and may subcontract the

investigation of a problem rather more rapidly, thereafter managing it. A private owner may have some technical professionals experienced in dam engineering. A power company, for example, is more likely to employ electrical or mechanical engineers than civil engineers experienced in dam engineering.

Owners in the government sector are sometimes able to take a wider view, having the manpower to invest in at least beginning the process of solving operational problems.

REGULATORY AUTHORITIES

These are powerful national or state organisations that are more commonly found in the developed countries. In Austria for example there is the Dam Supervisory Office. In Pakistan..... ? [other developing countries?]. In the US each Federal State has its own Department of Dam Safety. Regulatory authorities establish standards for design and construction and impose regulations on those working in the field of dam engineering. The matters under regulation most often include environmental matters. Some authorities are empowered to approve plans before they are put into effect.

Regulatory authority issues become much more complicated in multi-jurisdictional and trans boundary situations such as when dams are jointly owned and when two or more countries have land occupied by the reservoir, watershed, sediment discharge, irrigation benefits, and flood impacts.

FUNDING ORGANISATIONS

These are enabling authorities of great influence. They serve to identify projects that fit their criteria and to develop them. Where a project meets their sometimes restricted criteria they are effective in putting it in progress and monitoring its progress. Some of them can be bureaucratic, but their good will is important. Funding agencies are interested in different aspects of dam management. For instance, the World Bank has set up a number of rigorous safety standards and are mainly involved in upgrading the safety of existing dams. It is not involved in the construction of new dams. The European Investment Bank (EIB), the Arab Fund for Economic and Social Development and the Kuwait Fund are more involved in dam construction. Other relevant funding organisations include the UK Department For International Development, the German Kreditanstalt für Wiederaufbau (KfW), NORAD, the Asian and African Development Banks and many others.

PRIVATE SECTOR

It should be pointed out that dam owners and operators generally relies on engineers for the diagnostic work as well as the countermeasures when leakage or other problems are detected or suspected. The engineering consultants and subcontractors are therefore be the end-user of nuclear technology methods. Most of these engineering companies can be found in the private sector.

Consultant

The specific work undertaken by dam engineering consultants is outlined in some detail in annex III. Consultants are generally selected for projects by owners on the basis of qualifications and expertise.

There are two broad categories of consulting engineers. Large state owned enterprises were established in some countries to meet a national need and these have continued to make their services available commercially. Examples include the US Bureau of Reclamation (USBR) and the US Army Corps of Engineers in the USA, and Water and Power Development Authority (WAPDA) in Pakistan. A second category includes large and more or less specialised firms such as Brown & Root, Dames & Moore, AFRICON, TAMS, Binnie, and Lahmeyer. These have developed from small firms specialising in related fields and have grown through effective operation and now operate internationally. Many have a pedigree of 100 years or more and have the technical and commercial strength to deal with very large projects, such as TAMS at Tarbela Dam in or Binnie at the Mangla Dam in Pakistan.

Consultants are sometimes smaller and more specialised, bringing in academic and other external resources when necessary. This arrangement is found in Latin American countries more than elsewhere.

The number and size of consultant firms are growing in developing countries as the cost of technical staff from industrialised countries increases. Increasing is the tendency for consultants to work together so that the developing country firm absorbs the technical and management skills through doing the bulk of the work. Thus these firms are prospering in the Middle East, the Indian Subcontinent and in the Tiger economies of the far East.

Large consultants often sponsor and undertake research and development in technical areas they judge will give them a competitive edge in the future. Many of these areas have been in dam design and reservoir management. Isotope technology may be a case in point.

There is a tendency for consultants either to be large, or to be small and specialised. Specialist firms sometimes have strong links to academics and they work at the state of the art, integrating their research work with consulting activities. There are indices of such firms and they are frequently present at meetings of the International Commission on Large Dams (ICOLD) and conferences of the American State Dam Safety Officials (ASDSO). They depend for their success on being known, often personally, to the consultants or contractors for whom they work.

Contractors

Dam projects are usually constructed by either an individual or a joint venture of contractors. The cost of a large dam will be up to US \$ 100 Million, with many being in the order of US \$ 50 million. Only robust organisations are capable of managing the risks inherent in constructing such projects. Contractors are usually selected for projects by owners on the basis of lowest cost.

In developing countries and those with either a current or recent experience of a command economy, contractors are often state owned. This is unusual elsewhere except where organisations were set up to achieve a specific national goal. The Hydroelectric Commission of Tasmania for example. Most of the international contractors are now in private hands.

However, they are facing determined competition internationally from state owned firms from countries like China.

Major contractors are risk management businesses. They frequently buy in the specialist services they need, keeping a relatively small staff of technical professionals to manage the input. Few carry out much in the way of research and development, although there are signs that this might be changing.

There appears to be an increasing trend, parallel with the wish to privatise industries that were once held by the state, for contractors to adopt an entrepreneurial approach. In this role they are keenly interested in the development of technologies that will improve the performance of a project. Isotope technology might be appropriate in these circumstances. For example, the fingerprinting of water and also of sediments could be seen by them as cost effective solutions.

There are also specialised contractors who operate as main contractors on repair or small rehabilitation work, but whose size makes them perform more often as subcontractors, providing specialist services to an owner or a contractor. Hence instrument suppliers, drilling companies or underground treatment specialists often fall into this category for dam projects.

DAM PROJECT IMPLEMENTATION UNITS

These are units specifically created by national organisations to prepare and supervise national dam projects. The existence of such a “National Executing Agency” is often a requirement of international funding authorities, in particular for large projects. Since these units will need to carry out studies and generate decision-making information, they can also be seen as end-users for isotope techniques.

INSTRUMENT-MAKERS (??)

Mr. Sims, please

RESIDENTS

People living within the reservoirs of proposed dams will be severely impacted by the project, because they will need to be relocated. For example, Tarbela Dam required that almost 100,000 people be relocated to five towns that had to be built. The Three Gorges Dams in China require the relocation of about one million people [?]. These people are a major stakeholder group in a dam project, and much publicity is being given worldwide to such situations.

Conversely, dams and reservoirs once they are built tend to attract people to live near them. This new population tends to start occupying land downstream of the dam. Eventually they become attuned to the notion that a dam is a potential hazard, and start viewing it with some trepidation. These people also become stake-holders and often demand repairs and upgrades that were not anticipated when the project was originally planned.

Regulatory authorities can upgrade the hazard rating of a dam if people start living and working downstream. Such upgrades typically include increasing the spillway capacity to convey an increased design flood, stabilizing the dam for resistance to a higher earthquake risk rating and providing increased seepage control or leakage repair.

1c. Programme priorities

Lessons learned

For two dam projects in Venezuela and Pakistan, where leakage from reservoirs were suspected, relatively simple isotope fingerprinting (comparison of isotopic composition in water) proved that the water emerging downstream of the dam, thought to be a leak, actually originated from another source and not the reservoir. Therefore it was determined that a leak existed and repair investments were not needed. Hence, isotope fingerprinting has the potential to save dam operators very large sums by determining - in very short time - if water appearing downstream originates from the dam or not and thus whether repair work is at all required.

Three entry points of leakage through a concrete dam in Venezuela were identified by using isotope hydrology methods after conventional methods had confirmed that the dam leaked. The entry points are now being plugged by conventional diving methods. This is an example of using isotopes to complement other methods when their limitations were reached.

A few lessons have emerged from experience in the application of isotope techniques to address dam management problems:

- the problem should be well defined by the dam operator or his consultant, and this must be explained clearly to the isotope scientists who may have no knowledge of dam engineering.
- problems that are limited spatially and allow time to carry out the investigations calmly are particularly well suited to isotope technology. An exception to this is isotope fingerprinting to identify the origin of downstream suspected leakage which can be done in one day.
- the partners (laboratories and end-users must gain experience, not only in understanding each other's needs in contributing to the solution of the problem, but also in appreciating what the technology can do and not do.

Opportunities

Isotope hydrology appears to be equally well adapted to solving problems at large and small dams. An important aspect is the skill and experience of the isotope scientists and the way in which they work with dam owners, consultants and contractors.

Several isotope techniques can be considered unique tools for dam management. Some of these were identified as having a primary role for investigating certain types of problems common to dam management. Three techniques should be considered a high priority for programme planning:

- investigation of isotopic "fingerprints" to identify the origin and pathway of water in the hydrological cycle during all phases of a dam project from planning through operations
- investigation of sedimentation in the reservoir resulting from erosion in the watershed during the first filling and subsequent operations for purposes of managing the sediment

- investigation of leakage pathways through and around the dam and through the reservoir floor during the first filling and subsequent operations, if leakage is observed

While these investigations were found to offer unique information for dam management, other techniques are valuable for confirming or elaborating geochemical and physical investigations. When prioritising between applications of isotope hydrology in dam safety and sustainability, TC should prioritise cases where the applications have a causative or catalytic roles for solving a development problem.

2a. Basic requisites for the success of national activities

A check list follows of the requisites that should be considered to assess the likely success of a project in dam safety and sustainability. It will be almost impossible to fulfil all of them, however a critical review of their overall balance will provide a good judgmental indication.

Technical level

- Existing problems related to dam safety and sustainability
- A need for isotope hydrology analysis to address the problem, as identified through an IAEA mission, team evaluation or other mechanism (see sub-sections 1a and 3a)
- A time frame which would allow nuclear techniques to generate information on time to influence decisions

Country level

- National commitment to improving dam safety (e.g. through the existence of a major national dam safety programme, with external support through the World Bank or other funding agencies)
- Laboratory for isotope analysis existing in the country
- Successful history of the use of isotope hydrology available (if this is not the case, TCDC and regional collaborative arrangements could be considered)

End-user level

- Identification of the problem(s) and measurements of key indicators such as leakage rates
- Some possible solutions elaborated, but no tendency to impose/ enforce a pre-established solution
- Keen interest in solving the problem(s)
- Considerable funds provided by dam authority towards the solving of the problem (in money terms or in kind)
- The selected solution should not involve operation and maintenance (O&M) costs which are not sustainable by the owner.
- Complementary disciplines to form a suitable team are available, if this is required for solving the problem; the Agency should make the selection. The team composition will vary from case to case, but it should at least include a) a dam manager, b) an isotope hydrologist and c) a geologist/hydrogeologist

Regional collaboration, use of advanced centres and TCDC

AFRA and ARCAL have already addressed dam leakage problems. Teams were developed representing the usual dam investigation disciplines and isotope hydrology so that a range of dam leakage investigations could be undertaken. The team included isotope hydrologists, dam engineers hydrogeologists (should have hydrochemistry and isotope background) and geotechnical engineers or engineering geologists.

AFRA has developed some of the more advanced centres in the region (South Africa in the south, and Egypt and Algeria, in the North). Teams selected and trained by the IAEA can be mobilised on short notice. A questionnaire sent out through the AFRA counterpart resulted in more than 40 dams with leakage problems being identified. The severity and national priority of these leakage problems are yet to be determined. A series of diagnostic team missions are currently being carried out and funded by AFRA/IAEA, the African Development Bank, the World Bank, etc. AFRA members submitted requests for investigations, evaluated the requests, and prioritised them according to safety, socio-economic value or other reasons.

AFRA members with presently no or little nuclear facilities expertise are benefiting from the regional expertise and facilities. At the same time, technology transfer and training are being established or initiated in those developing countries.

2b. Limitations and constraints for IAEA TC

The use of isotope hydrology in dam management is unique in some applications (water fingerprinting and sediment tracking), and complements conventional technologies in other applications (identifying water pathways and finding leak sources). TC should help member states acquire and use isotope techniques and, in some cases, use complementary technologies in order to complete a study.

The limitations for TC are determined by the state of validation of the techniques and by national legislation. Only proven and validated technologies should be recommended for TC application and to address problems in the field. For radioactive isotopes, the principle should be that the expected value of the information should exceed the risk in handling the radioactive material. If a problem can be solved without using radioactive tracers at a comparative cost, the conventional technique is to be preferred.

Since 1957, approximately 35 isotope hydrology laboratories have been installed or upgraded by the IAEA around the world. Over 1,000 people in developing countries have been trained in a steadily growing isotope hydrology programme over the past 10 years. Advanced centres for the application of isotope hydrology exist around the world. Lead centres are being identified through AFRA and ARCAL (?). The availability of laboratory infrastructure makes the application relatively inexpensive. However, in the context of dam investments the typical cost involved in a TC project in this field - approximately \$50,000 to \$200,000 is a small investments in relation to the potential savings from informed decision-making.

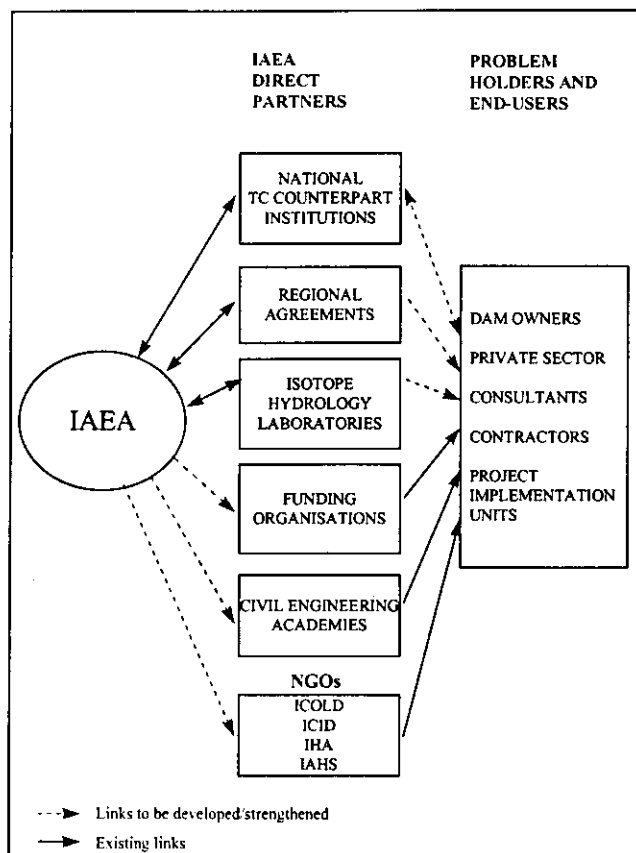


Figure 1: Reaching the end-users

2c. Roles and partnerships

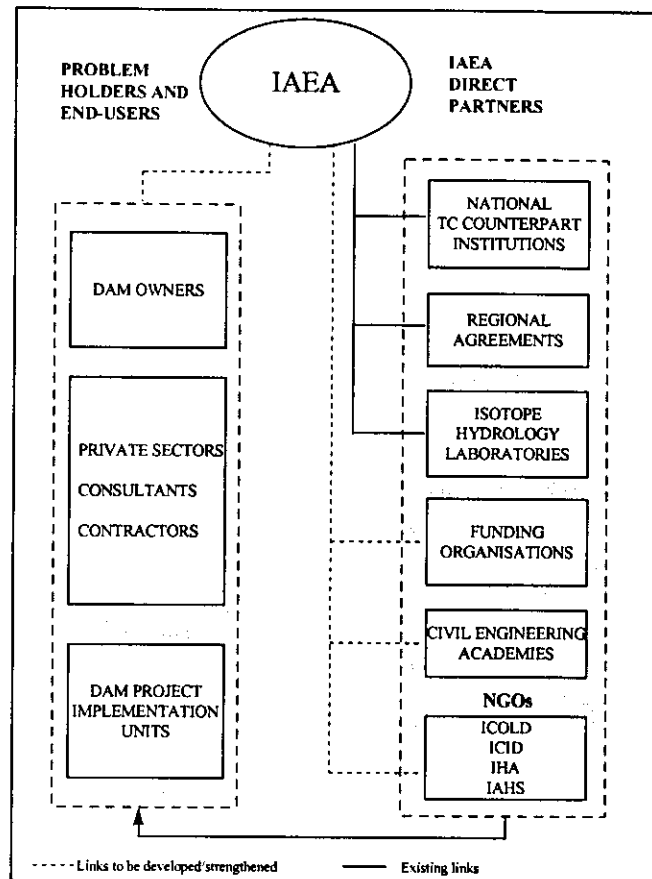
Outreach

The TC approach for achieving project impact is to reach the end-user - the last link in the chain that connects the Agency counterpart with the problem holder. Reaching the end user is the fundamental measure of success for TC projects and the key concept underlying the TC Strategy. Since most of the end-users of analytical technology for dam safety and sustainability are commercial enterprises, interaction with the private sector is crucial to ensure the successful application of isotope techniques in this area. This presents a special challenge since the IAEA generally does not deal directly with the private sector.

The main objective for the Agency's strategy must therefore be to bridge the gap between the technology providers and the problem-holders and to foster partnerships that would help achieve this objective. If the applications are proven useful for the end-users, ultimately, the commercial application should guarantee that a sustainable demand will develop. The current situation is outlined in the figure (1). Partnerships to be developed are marked with dotted lines. Over time, the objective is to arrive at the situation in figure (2), whereby information flows from the Agency and its direct counterparts to the end-users, and the Agency receives feedback - through evaluations, through its partners and through an increase in government interest - on the impact of nuclear technology in dam safety and sustainability. The Agency should continuously monitor these results and seek feedback on the success in the medium term, and for this purpose, a regularly convening thematic planning co-ordination group should be considered.

Figure 2, Desired information flow

The IAEA's direct partners for Technical Co-operation are Government-assigned National TC Counterpart Institutions. On the project level, the Agency collaborates with isotope hydrology laboratories around the world. In addition, formal links exist with UNDP and FAO, emerging links with the World Bank and UNICEF and more unstructured links with other UN agencies, development banks and bilateral aid agencies. The thematic planning in dam safety and sustainability has added an emerging partnership with ICOLD to this list. The Agency can help achieve the objective stated above by strengthening its links with funding organisations in the dam and reservoirs sectors and with NGOs, in forms that are outlined below in sub-section 3a. In addition, linkages with the civil engineering faculties of universities of technology would help integrate nuclear techniques into dam engineering.



There are few examples where working relations have been created between the Agency's national liaison offices and counterpart authorities and end-users in dam management. One such example is Venezuela where a dam owner approached the national liaison office. Another is South Africa where a dam engineering consulting firm uses the laboratory support of the national atomic energy commission. Within AFRA, the national counterparts have been requested to strengthen their links with dam owners.

One of the most crucial partnerships is that between IAEA's counterparts in isotope hydrology laboratories, many of which are primarily oriented towards research, and the end users. Such a link has the potential to benefit both parties. The end users will do well economically if the isotope technologies are successfully used. The institutes will grow and flourish if the technologies are successful because more dam projects will want to make use of isotope hydrology. This kind of partnership will be of particular importance for the many isotope hydrology institutes, such as PINSTECH in Pakistan and CNESTEN in Morocco, that are operating in a semi-private environment, as their Governments require them to cover some of their budget through independent work.

Programme convergence and in-house synergies

Implementation strategy

The implementation strategy consists of three interrelated components:

(1) Problem Identification - Joint Missions

This component aims to strengthen donor co-ordination, ensure that the Agency's activities are integrated with national plans and programmes and help generate a number of success stories which could be disseminated to a wider audience.

The TC department should strengthen its links with international funding organisations with dam programmes, including the World Bank and the European Investment Bank. The Agency should initially participate in a number of World Bank missions where the condition of adequate counterpart structure and relevant problems are expected to be met.

The first aim of the Agency's participation in such missions should be to conclude whether nuclear techniques can help solve the country's problems in the dam sector. If a need for isotope hydrology applications is identified, the Agency should indicate where available technical infrastructure exists. Efforts to address the identified problems could be incorporated into IAEA CPFs and to existing projects. Activities should be co-ordinated with and build on the activities of the regional agreements.

With the help of the World Bank, a list of countries has been developed, which fulfil the criteria of Government commitment and existing dam problems (see sub-section 3b).

(2) Expanded Informational Activities

An aggressive information campaign should be launched to inform the end users of the benefits of isotope hydrology in dam management. Direct partners in this exercise are NGOs - in particular ICOLD - and international organisations. Other potential partner organisations with end-user participation are ICID (irrigation), IHA (hydropower) and IAHS (hydrological sciences), as well as the Association of State Dam Safety Officials (ASDSO) in the US, Hydropower and Water Supply Associations and professional engineering associations.

The following recommendations were made by the thematic planning consultant meeting:

- * the IAEA should submit a paper and organise an information booth on ICOLD's three-yearly Congress in October 2000 in Beijing and its annual meeting in Antalya, in October 1999.
- * The Agency should develop a dam management neighbourhood on its web site and try to link this to the web sites of ICOLD, ICID, the World Bank and other partners.
- * The Agency should consider developing a technical document (TECDOC) to replace the existing one which forms part of a larger document from 1991
- * The convening of a joint IAEA/ICOLD seminar on isotope hydrology in dam engineering should be considered, when more success stories have been generated.
- * Through specialist workshops and regional collaboration, the Agency could play a role in making counterparts mindful of private sector and commercial interests, as well as their potential contribution towards solving problems being experienced by the end-user.
- * The IAEA should participate in international congresses and conferences by writing high quality papers, and making presentations of isotope hydrology and other techniques, highlighting successful case studies, illustrating the results obtained, and showing how they may be economically compared with conventional techniques. Exhibitions and advertising booths should be provided at these events.
- * The IAEA should disseminate information on available resources through listing of techniques, applications, laboratory facilities and contact points.
- * Isotope hydrology must be taught in civil engineering courses at universities if it is to become a tool of dam management. The initial universities to approach could be Imperial College in London, Massachusetts Institute of Technology in Boston, University of Toronto in Toronto, and Ecole Nationale.

- * A modular Training Course might be prepared and given to professional engineering institutions, perhaps with the help of national liaison officers and counterparts. A significant milestone will have been reached when the term "isotope hydrology" appears in the index of civil engineering text books.
- * A short video could be prepared for educational broadcasts such as the Discovery Channel, and for civil engineering professors to use in lectures.
- * The section on problems and solutions in the Thematic Plan should form the basis for an information brochure to be developed as soon as possible. The target groups for this should be technology end-users and not the scientific community. This brochure should be present facts on the use of isotope hydrology and answering questions that the end users may have. These include:
 - What nuclear techniques comprise
 - How they may be used, case studies and pictures
 - How they compare with other options in terms of cost, accuracy and complexity
 - What are the risks of using them
 - How to recognise if they are useful to identify the cause of particular problems
 - Who offers this service
 - Who to contact if further information is needed?

(3) Validation of promising applications for future Technical Co-operation

Co-ordinated research programmes should be launched to develop and validate methods which were identified as particularly promising for applications in dam safety. In table 1, a number of such applications are identified (likely validation). The potentially most useful of these new methods is the tracking of sediments that cause dam outlets and reservoirs to become progressively filled with silt. It is proposed to pursue this and other promising applications through co-ordinated research and training, in co-operation with the World Bank.

The objective of these pro-active measures will be to build a demand for isotope methods in dam management which should, over time, lead to an increase in the requests for assistance in this area via the traditional channels. This will allow for the development of the thematic area of dam management through demand for isotope technology applications among end-users rather than technology supply. Table 2 gives an overview of the activities proposed in the implementation plan:

Table 2 - Responsibilities for implementation plan

Component	Activity	Responsible IAEA party
(1) Problem identification, joint missions	Development of partnerships with important funding organisations for dam projects and feeding relevant information to IAEA programmes	TC, NACP
	Participation in joint mission with donor organisations	TC, NACP
	Integration dam safety projects in CPF exercise and up-stream work	TC
(2) Information Campaign	Participation in congresses, submission of papers to ICOLD and other meetings and organisation of a joint IAEA/ICOLD seminar	NACP
	Dam safety link on IAEA home page	NACP, ADPI, TC
	Brochure	TC, NACP, ADPC
	Video	ADPI, TC, NACP
	TECDOC	NACP
	Modular training course	NACP, TC
	University Civil Engineering link	NACP
	Listing of resources in dam safety	NACP, TC (through regional agreements)
(3) Validation of	Targeted research	NACP

3b. Proposed countries for joint IAEA World Bank country assessments

The list below was prepared on the basis of the following criteria:

- Imminent World Bank appraisal mission
- World Bank Project either new or in initial phases of implementation
- Expected scope for isotope hydrology applications due to multitude of dams or specific problems

In the case of non-recipients of IAEA TC assistance, extrabudgetary assistance from the World Bank (including support costs in the case of non-member states) will be required, and made available if the task managers considers IAEA expertise to be of sufficient value to the success of the appraisal.

Box 2: Proposed Pilot Assessments

Albania : Irrigation and Drainage Rehabilitation Project II (14 earthfill dams project in preparation)

Central Asian States: Aral Sea Basin Program – WEAMP, Dam Safety Component, GEF project (pilot dam safety measures at 10 major dams)

Armenia: Dam Safety (23 large dams, project in preparation)

China: Tarim Basin II – construction of new earth-fill dams, impervious facings to existing dams

India - Dam Safety II (Project under consideration, 4 or 6 States, 30 to 40 dams)-

Indonesia - Dam Safety (under implementation)

Kazakhstan - (Safety of the Chardara dam, project in preparation)

Kyrgyzstan - abandoned uranium tailing dams (under consideration)

Kyrgyzstan - irrigation rehabilitation (12 dams)

Macedonia (One 60 meter high Dam, seepage problems, on-going project)

Mexico – Water Resources Management Pr. (Hazard Classification, ranking of risks for each dam, prioritisation of investments on the basis of risks)

Morocco – Water Resources management Pr. (reconstruction of the u/s face of Nakhla dam, on-going project)

Pakistan - Indus reservoir conservation project (Mangla and Tarbela Dams) (project requested by WAPDA, under consideration)

Vietnam - Irrigation Rehabilitation; (safety assessment of 4 earth-fill dams, on-going project)

ANNEX I

Highlights of successful integration of isotope techniques in dam management

- **Venezuela:** It has been calculated that the amount of US \$ 6 million was recently saved, as information generated through isotope techniques obviated the need for a full-scale engineering study in connection with a leaking reservoir. . Another isotope study determined that the ground water in the Valencia Lake Basin was contaminated by the nearby Taguaguay Water Reservoir, and not, as previously thought, by the Valencia Lake. The National Authority for generating electricity, CADAPE, has now commissioned a study, with IAEA support, of the deposition of silts which reduce the operational life time of water reservoirs and turbines in hydroelectric generating stations. Through isotope techniques, the critical sources of siltation in the Uribante Dam reservoir will be determined. The expected impact of this project will be a reduction of the sedimentation processes with the subsequent increase of the life of the reservoir that would help to increase the energy supply to the agro-industrial sector and the population of Tachira State. Another isotope study identified the entry locations of three leaks in the concrete Canoabo Dam after a conventional study confirmed that the dam had three leaks. The entry locations are now being sealed by conventional diving techniques.
- **Pakistan:** There were some areas around the zoned earthfill and rockfill Tarbela Dam which were partially affected by waterlogging. The landlords of the area related the waterlogging with the seepage from the Tarbela Reservoir on the Indus River. They claimed compensation for their lands affected by the waterlogging. The isotopic study revealed that there was no contribution from the Tarbela reservoir towards waterlogging in the area. The source of groundwater was the local rains. On the basis of isotopic studies, the case was dismissed by the court.
- **Costa Rica:** According to the President of the Costa Rican Atomic Energy Commission, the use of isotope techniques allowed the Instituto Costarricense de Electricidad to detect a potential land slide on the left bank of the Arenal Dam in time to take corrective action, avoiding serious safety problems in the dam structure. It was also possible to locate the source of water leakages causing water infiltration in a tunnel of the Angostura dam.
- **Morocco:** Isotopes techniques are being used to identify the origins of a leaks in the roller compacted concrete Aoulouz Dam. It is expected that the implementation of the engineering solutions to be outlined as a consequence of the tracer studies will help the Government saving a significant amounts of funds by enabling selective dam repair measures where they are most needed to prevent dam leakage.
- **Regional Africa, Latin America:** Within the framework of an intergovernmental agreement, specialised teams of African experts will systematically be evaluating dam leakages in more than 40 dams in Africa, building on the success in Morocco. Following regional IAEA support through the ARCAL programme, isotope techniques are now widely integrated in water management, and applied to trace leaks in dams and water reservoirs in most countries in Latin America.
- **Global:** Most of the Agency's developing Member States have developed capabilities in isotope techniques with IAEA support. 160 TC projects in 63 countries with an aggregate budget of more than 20 Million US \$ were implemented in the past 10 years. Efforts are now underway to link efforts in Latin America, Africa and Asia through collaboration between the intergovernmental agreements that deal with nuclear techniques AFRA (for Africa), ARCAL (for Latin America) and RCA (for East Asia and the Pacific).

ANNEX II

Isotope techniques in dam management to be validated through further research before their application in Technical Co-operation

VALIDATION

Sediment routing during peak turbidity inflow by real time density monitoring:

The technique is well established. Electronic systems have to be developed in order to provide the information according to technical requirements. Automatic electronic systems should allow to interrupt the measurement when no water is following along the river, or the sediment concentration is lower than an established threshold value. The installation of a second probe using an IR sensor can provide complementary information in the low concentration range. the combined use of the two probes is advised.

Density current monitoring:

Nuclear probes using ^{241}Am or ^{137}Cs can be used for this purpose. Both techniques are well established from the technical point of view. However, they have never been used for this application. A short investigation is needed for the identification of the way how the measuring probe can be introduced in the system to be measured. The characteristics of the electronic output of these probes needs to be defined by the final user.

Monitoring RSI (Reservoir Induced Seismicity) at specific geostructures.

The possibilities offered by the radon technique depend strongly on the lithological composition and texture of the involved rocks. Only under favorable conditions can the technique provide reliable information. The ideal condition is found with granitic or methapelitic rocks with a high degree of fracturation.

Monitoring seepage and leakage problems during first reservoir filling:

The investigation of this problem requires the combined use of different techniques. Some of them are routinely used by dam engineers in their normal work. When combined with isotope hydrology techniques, the information obtained may lead to a better identification of the problem and its mechanisms. The methodological approach should be to review:

1. design calculations, construction drawings and construction records
 1. piezometric variations in the boreholes;
2. measurement of temperature and conductivity profiles in boreholes;
3. single well technique using artificial tracers in boreholes, for the localization and measurement of groundwater flows;
4. flowrate measurement of springs by the dilution method with artificial tracers;
5. measurement of water infiltration rate at the bottom of the reservoir (seepage), using special devices developed by isotope hydrologists.

Localization of entry zones using ^{198}Au as an adsorbable tracer

Infiltration tests should be conducted at the banks of the reservoir using artificial tracers and flow direction mechanical devices

Leakage path within the dam body

The localization of such leakage paths can be only undertaken if appropriate boreholes are available in the area to be studied. The following well-established techniques are suggested:

1. review design calculations, construction drawings and construction records
2. review monitoring and maintenance records
 1. determine piezometric levels ;
 2. measure temperature and conductivity profiles in boreholes;
 3. measure profiles of wet density (gamma-gamma) and humidity (neutron-neutron), using nuclear probes;
 4. use single well and artificial tracers in boreholes, to localize and measure groundwater flows.

All these techniques can be periodically applied as a function of the level variation of the water in the reservoir. Periodically, water samples collected from these boreholes should be collected and analysed for chemical and isotopic composition to determine if it is coming from the reservoir or elsewhere. The profiles described in item 3 will provide information on the geotechnical behavior of the dam structure.

ANNEX III

Dam Engineering

Services in the field of dam engineering are typically carried out by an engineering firm (the Engineer) that has successfully completed other dam engineering projects, and is familiar with dam construction and operations. The engineering firm is typically hired by a firm or organisation (the Owner). In developed countries, these are most often private, whereas in developing countries the majority of dams are State-owned. An Owner may want to:

- Build a new dam
- Modify an existing dam
- Repair an existing dam

A NEW DAM

The engineering work for a new dam usually starts after the Owner has determined that a dam is required, and has either selected a site or identified two or more potential sites. The evaluations undertaken under the auspices of the engineer are summarised in box 1. The design of the dam is not complete until it has achieved its first filling because site conditions can differ from expectations and filling can reveal further surprises.

Box 1 - Engineering work for a new dam

The Engineer usually organises its work as follows:

- Watershed evaluation to estimate the quantity of water available on an annual basis and to determine the design operating flood and maximum probable flood.
- Seismic study to identify and classify the nearest faults, estimate the magnitudes of the design operating earthquake and maximum credible earthquake, and calculate a design ground acceleration.
- Site selection study to confirm the most suitable dam location and the best alignment there for the dam axis
- Dam sizing evaluation to determine the optimum height of the dam to store the required volume of water.
- Sedimentation evaluation at the watershed to estimate the rate and physical characteristics of sediment deposition in the reservoir, and calculate the minimum life of the dam
- Site geotechnical investigation and laboratory testing to confirm the subsurface conditions of the dam and reservoir areas.
- Materials investigation to identify types and volumes of local materials that can be used for construction.
- Dam type selection, earthfill, rockfill or concrete, based on foundation conditions, topography, construction materials and preliminary cost estimates.
- For earthfill and rockfill dams, design of zoning to maximise the use of local materials.
- Design of dam to assure stability and seepage control through the dam and from the reservoir.
- Design of the spillway and outlet works to convey the required normal flows, and emergency flows resulting from storms and floods.
- Design of instrumentation, for measuring water levels in the dam, movement and deformation of the dam, and collection of seepage downstream.
- Preparation of drawings, specifications and bid and contract documents for the construction works.
- Preparation of construction schedules, cost estimates and critical path.
- Construction monitoring to ensure that the dam is constructed in accordance with the designers intent and to incorporate changes necessitated by unexpected site conditions.
- Operation and Maintenance plan, including regular inspections written for practical people.
- Emergency Action Plan, also written for non technical people.

MODIFY AN EXISTING DAM

Modifications are called for by the owner of an existing dam

- When a dam is to be raised to provide additional storage.
- When new hydrological data show that increased spillway capacity is required.
- When new seismic data shows that the dam has to be strengthened.

Similar design procedures are used as outlined above for a new dam. An important consideration is to obtain as much relevant data of the original design, construction and operation as possible. Communication with dam operating staff is essential .

Frequently there are national regulations that either trigger the requirement or determine the content of the analysis required.

REPAIR OF AN EXISTING DAM

Repairs of existing dams are required when some of the following phenomena are observed in the dam or the foundations:

- Excessive or uncontrolled seepage or leakage: internal erosion, sinkholes
- Unacceptable movements or deformations: settlement, bulging
- Weakened or degraded materials: slope protection, chemically attacked concrete,
- Damage due to overtopping: erosion
- High pore water pressure: instability.

Similar design procedures are used as outlined above for a new dam. An important consideration is to obtain as much relevant data of the original design, construction and operation as possible. Communication with dam operating staff is essential .

Although a programme of repairs to a dam is usually driven by the Owner, frequently national regulations that have to be complied with, although this is more common in the developed world.

ANNEX IV
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